UDC 666.11.01:535.343:620.1

REGRESSION EQUATIONS FOR DETERMINING LIGHT TRANSMISSION IN TINTED FLOAT GLASS

N. N. Shcherbakova,[1] V. I. Kondrashov,[1] I. A. Kupriyanova,[1] and V. A. Gorokhovskii[1]

Translated from Steklo i Keramika, No. 5, pp. 10 – 11, May, 2001.

Using methods of mathematical statistics, a model is developed in the form of a linear regression equation, which adequately describes light transmission variations in bulk-tinted float glass in the visible and IR spectra, depending on the variation of the main technological parameters.

For more than 20 years, the Saratov Institute of Glass has been manufacturing light- and heat-shielding glass on its own float-glass production line. The main production volume consists of bulk-tinted glass with special optical and thermal functions, which ensures better labor conditions and light comfort, as well as an additional decorative effect and architectural expressiveness [1].

The Institute has developed the concept of expanding the float-glass production based on manufacturing a wide range of glasses of various tints and degrees of light transmission, which are made on the same production line, involving transitions from one glass variety to another [2]. Research is carried out with the aim of refining the technology of obtaining preset tint and light transmission in glass.

The prediction of light transmission of glass in transition from one color shade to another, with variations in the composition of glass and the instability of technological processes, has been the object of numerous studies. The present paper considers a line of research of the formation of light transmission in glass depending on the following factors:

– the total content of iron oxides in glass based on chemical analysis data Fe_2O_{3tot};

– the content of bivalent iron oxide (FeO) estimated on the basis of measurements of the optical parameters of glass;

– the amount of metallic selenium and cobalt introduced into the batch.

The purpose of the study was to determine the effect of these factors on light transmission in tinted glass.

Glass samples with a known total content of iron oxides were selected for analysis. The light transmission in the visible spectrum range was measured on a spectrophotometer with a wavelength measurement range of 380 – 720 nm. A spectrophotometer with a measurement range from 250 to 2500 nm was used to measure the infrared radiation transmission. The FeO content in glass was determined photometrically. The method is based on measuring the integral transmission of a narrow part of the spectrum in the absorption-band range of ferrous oxide (II).

The instrumentally measured transmission in the IR spectrum was used to find the optical density value based on the table of conversion from optical density to transmission, and then the content of ferrous oxide (II) is calculated from the formula

$$T_{\text{nom.l}} = T_{\text{inst}}/0.92 \to D_{\text{nom.opt}};\ \text{FeO} = 10D_{\text{nom.opt}}/9.86d,$$

where $T_{\text{nom.l}}$ is the light-transmission coefficient; T_{inst} is the reading of the measuring instrument dial; 0.92 is the coefficient taking into account the reflection of the glass surface; $D_{\text{nom.opt}}$ is the nominal optical density (found from Table 1); 9.86 is the specific absorption factor for 10-mm thick glass with an FeO content of 1%; d is the glass thickness, mm.

Based on the data of actual measurements of light transmission in the IR range in the glass samples from the ÉPKS-4000 production line, a regression equation was constructed from 60 values:

$$Y_{\text{IR}} = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4, \tag{1}$$

where Y_{IR} IR is the light transmission in the IR range; X_1 and X_2 is the mass content, %, respectively, of FeO and Fe_2O_{3tot} in glass; X_3 and X_4 is the quantity of selenium and cobalt, respectively, added to the batch, g.

The verification of the obtained estimates for coefficients a_i in Eq. (1), employing the Student t-distribution revealed an insignificant difference from zero in coefficients a_3 and a_4 even for the 20% level of significance. The respective terms were consecutively excluded from Eq. (1), and the estimates of the remaining coefficients were calculated and analyzed

[1] Saratov Institute of Glass, Saratov, Russia; Saratov State Technical University, Saratov, Russia.

0361-7610/01/0506-0164$25.00 © 2001 Plenum Publishing Corporation

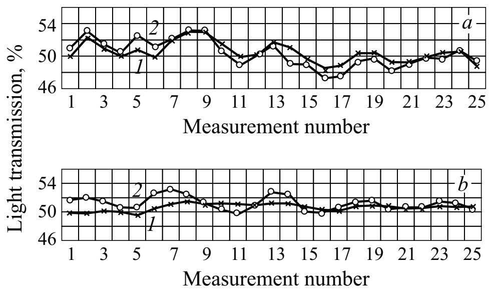

Fig. 1. Correlation between estimated values of light transmission (*1*) and practical data (*2*): *a*) IR spectrum range; *b*) visible spectrum range.

based on the *t*-distribution. As a result, the final regression equation was obtained:

$$Y_{IR} = 79.31065 - 326.2026X_1 - 10.57108X_2 . \quad (2)$$

Both remaining coefficients differ significantly from zero for the 20% significance level, whereas the coefficients of X_1 differs from zero for the 1% significance level.

A similar model describing light transmission in the visible spectrum range proved to be inadequate. However, when the ratios of Se and Co additives to the content of FeO and Fe_2O_{3tot} in glass were taken as variables, the respective regression equation acquired the following form:

$$Y_{vis} = 46.74621 - 1.29647Z_1 + 9.37741Z_2 + 7.51569Z_3 + 45.7069Z_4, \quad (3)$$

where Z_1, Z_2, Z_3, and Z_4 are 0.01(Se/FeO), 0.01(Se/Fe_2O_{3tot}), 0.01(Co/FeO), and 0.01(Co/Fe_2O_{3tot}), respectively.

The Student *t*-distribution revealed a significant difference from zero in all coefficients in Eq. (3) for the 5% significance level.

Thus, the quantities of added Se and Co do not have a significant effect on the light transmission of bronze-tinted glass in the IR range. The most effective is the content of FeO in the glass, and the higher this content, the lower the value of Y_{IR}. The light transmission in the visible spectrum range is considerably affected not by the absolute content of FeO, Fe_2O_{3tot}, Se, and Co, but by their ratios.

The coefficients in regression equation (1) were estimated using the least-squares method. To implement this method, programs were developed in MS Visual Basic for Excel. The MS Excel program also solved the problem of using Eqs. (2) and (3) for theoretical prediction of light-transmission values both in the IR range and in the visible range. The obtained values for bronze-colored glass were compared with the data of light-transmission measurements in glass produced on the specified production line during 4 months of the current year (Table 1 and Fig. 1).

TABLE 1

Date	Light transmission					
	IR spectrum range			visible spectrum range		
	estimated values	practical data	deviation	estimated values	practical data	deviation
10.01.00	49.88	50.90	– 1.02	49.86	51.70	– 1.84
17.01.00	52.27	53.10	– 0.83	49.74	52.00	– 2.26
20.01.00	50.85	51.40	– 0.55	50.16	51.50	– 1.34
24.01.00	49.98	50.40	– 0.42	49.97	50.60	– 0.63
01.02.00	50.75	52.50	– 1.75	49.50	50.60	– 1.10
07.02.00	49.87	51.10	– 1.23	50.43	52.70	– 2.27
10.02.00	52.04	52.10	– 0.06	51.02	53.20	– 2.18
14.02.00	53.12	53.10	0.02	51.53	52.50	– 0.97
17.02.00	53.12	53.10	0.02	51.08	51.20	– 0.12
22.02.00	51.38	50.50	0.88	51.26	50.40	0.86
28.02.00	49.75	48.80	0.95	51.10	49.80	1.30
02.03.00	49.97	49.90	0.07	50.86	50.80	0.06
09.03.00	51.60	51.20	0.40	51.24	52.90	– 1.66
13.03.00	51.06	49.00	2.06	51.28	52.50	– 1.22
16.03.00	49.54	48.80	0.74	50.73	50.10	0.63
20.03.00	48.46	47.20	1.26	50.24	49.80	0.44
23.03.00	48.78	47.40	1.38	50.21	50.70	– 0.49
27.03.00	50.30	49.20	1.10	50.81	51.40	– 0.59
30.03.00	50.41	49.60	0.81	51.00	51.60	– 0.60
04.04.00	49.16	48.10	1.06	50.69	50.50	0.19
10.04.00	49.11	48.90	0.21	50.60	50.70	– 0.10
13.04.00	49.76	49.60	0.16	50.50	50.70	– 0.20
17.04.00	50.30	49.60	0.70	50.81	51.50	– 0.69
24.04.00	50.52	50.70	– 0.18	50.64	51.20	– 0.56
27.04.00	48.78	49.40	– 0.62	50.87	50.40	0.47

The mean deviation from the theoretically estimated value was 0.21 in the IR range and 0.59 in the visible range, and the respective quadratic deviations were equal to 0.18 and 0.20.

The greatest divergence between the theoretical and practical data was observed during the transition period, when the formula of the batch additives was modified.

Consequently, the difference between the estimated and practical (actual) values with 95% probability lies within the interval from – 0.17 to + 0.58 for the IR spectrum range and from – 1 to – 0.19 for the visible range. This is evidence of the validity of the obtained model for predicting light transmission.

REFERENCES

1. V. I. Kondrashov, N. N. Shcherbakova, Yu. V. Zverev, and V. V. Skokshin, "Certain aspects of the formation of color in sheet glass," *Steklo Keram.*, No. 10, 8 – 9 (1998).
2. V. I. Kondrashov, Yu. V. Zverev, E. G. Mukhina, and V. V. Skokshin, "Color characteristics of a parametric series of heat-absorbing tinted glasses," *Steklo Keram.*, No. 4, 7 – 8 (2000).